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A fast rotating superfluid on a curved surface

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Ultracold atom experiments enable the study of quantum systems in a very controlled and tunable environment. In particular, they offer a natural playground for the study of superfluid dynamics, made possible by the existence of interactions between atoms. Superfluids are characterized by an ensemble of specific properties, including the absence of viscosity, existence of a critical velocity for excitation, and the irrotational character of a superfluid flow.

In the presence of applied rotation, trapped superfluid develop a number of quantum vortices that arrange in a regular triangular lattice at very low temperature, the Abrikosov lattice. As temperature increases, however, the Abrikosov lattice is expected to be gradually destroyed, by displacement of the vortex centers and eventually strong phase fluctuations.

In our experiment, we rotate a rubidium quantum gas in a very smooth oblate potential arising from a combination of magnetic and radiofrequency fields. We image the vortex lattice after a time-of-flight expansion and characterize the order of the vortex lattice by measuring the correlations between vortex positions, as a function of the temperature and the rotation frequency. We observe the melting of the vortex lattice at large rotation frequency and finite temperature.

Finally we make use of the peculiar geometry of the trapping potential, a smooth shell-shaped surface to access a regime of supersonic rotation, in which the superfluid forms a dynamical ring.

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